Near/Mid-Infrared Heterogeneous Si Photonics

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Leveraging the well-established and high yield manufacturing processes that were initially developed for micro-electronics, silicon photonics holds a great promise in optical interconnects, computing, sensing, etc. for superior performance, cost-effectiveness, and lower power consumption. However, on the other hand, the inherent properties of the silicon material puts a question mark on certain functionalities that silicon photonics may not be able to deliver. For example, the indirect bandgap of the silicon material prohibits efficient light emission, which is essential for an optical communication system. In the meanwhile, silicon dioxide starts to absorb light strongly beyond 4 μm, which is an important wavelength range for sensing where most molecules have their absorption fingerprint. To overcome these limitations, great efforts to monolithically integrate various semiconductors on silicon have been devoted over the past decade and very exciting progress has been made. In this paper, we will present an overview of our recent results on near/mid-infrared photonic applications that are enabled by epitaxially growing high quality semiconductors on silicon.

III-V materials currently dominate the market of near-infrared semiconductor lasers. The monolithic integration of III-Vs on silicon would provide the final missing piece of silicon photonics – on-chip laser sources. We have demonstrated selective growth of large arrays of InP nanowire lasers on silicon (see Fig. 1a), showing the great potential of CMOS compatible integration of InP material on silicon at the wafer level. Recently, by taking a step further, we have demonstrated InP waveguides grown on silicon with superior material quality (see Fig. 1b). It paves the way to a fully integrated in-plane III-V laser on silicon.

While silicon dioxide absorbs above 4 μm, germanium's window extends to 14 μm. Given that germanium has a higher refractive index than silicon, germanium-on-silicon can be a promising platform for integrated photonics in that wavelength region. Low waveguide loss in the 5-5.5 μm range has been achieved (see Fig. 2a), and basic components such as concave grating wavelength (de)multiplexers have been demonstrated (see Fig. 2b). Besides germanium also GeSn structures can be grown to extend the functionality of the silicon photonics platform (e.g. short-wave infrared photodetectors). Also this will be discussed at the conference.

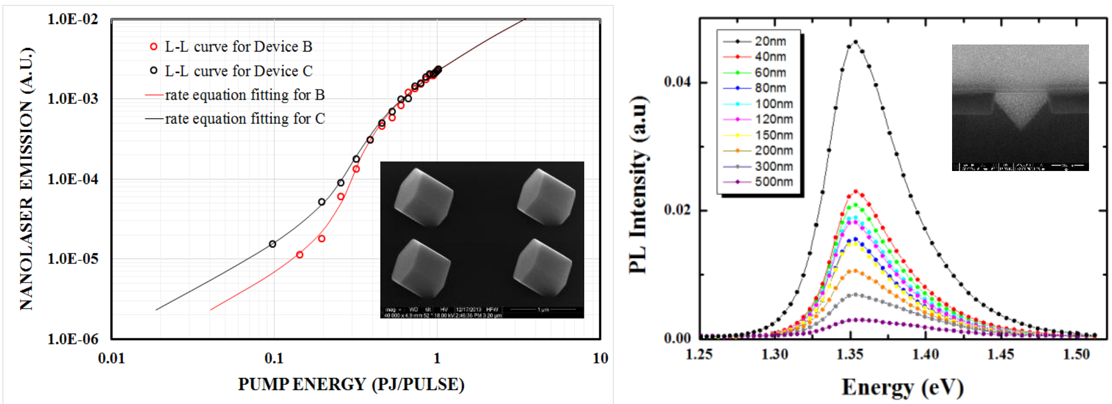

Figure 1. (a) The light in-light out curve of two InP/Si nanolasers measured at room temperature. The circles are measured points and the solid curves are the rate equation fittings. Insert : SEM image of a two-by-two nanowire laser array. (b) Photoluminescence spectra measured from InP-on-Si waveguides with different widths. Inset : SEM cross-section image of an InP-on-Si waveguide.

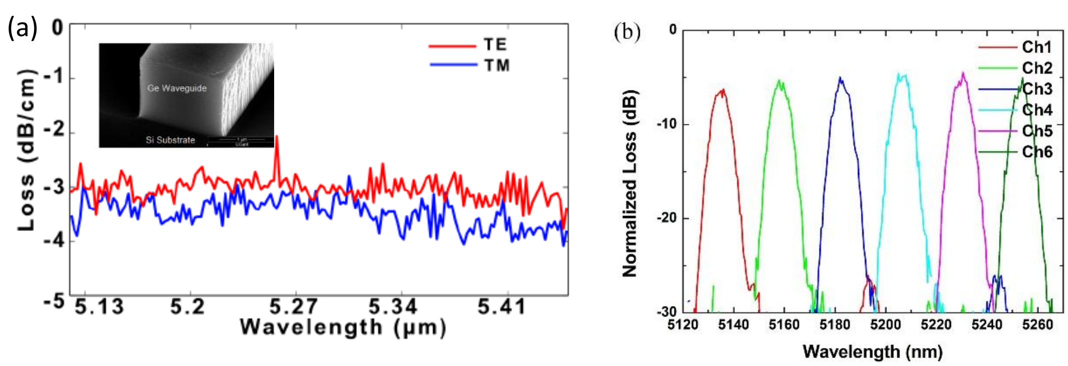

Figure 2. (a) Measured loss in the germanium-on-silicon waveguide for both TE and TM modes. Insert : SEM image of germanium-on-silicon waveguide. (b) Normalized spectrum of a six channel planar concave gratings with DBR gratings.

In conclusion, monolithic integration of other semiconductors on silicon brings new dimensions to silicon photonics, which enable a wide range of new and exciting applications.